Precision Agriculture and its Future

Abstract

Natural resources, biotic variables, agro-inputs, and management all impact agricultural production. Uncontrolled use of resources and inputs frequently occurs by farmers, which results in environmental pollution, degradation of land, and financial loss to farmers. The term "precision farming" describes the integration of GIS and GPS tools to provide extensive detailed information on crop growth, crop health, crop yield, water absorption, nutrient levels, topography, and soil variability (Adrian et al., 2005). Precision agriculture makes use of technology such as sensors, GPS, GIS, Internet of Things, drones, etc., among other things, to optimize the use of natural resources and farm inputs for a given crop production and quality. Agriculture could become more productive and consistent due to digital agriculture and more effective use of resources and time. This article presents the gist of Precision Agriculture along with its components and future implications.

Keywords: Precision, Technology, GPS, Remote sensing, Drones.

1. Introduction

Natural resources, biotic variables, agro-inputs, and management all impact agricultural production. It can only be a sustainable venture if there is harmony in the above interactions. Agriculture employs a large section of the population in emerging countries, such as India, where 54 per cent of the population is directly or indirectly involved in agriculture and related industries. Though, the contribution of this sector to the nation's GDP has been 20 per cent in the year 2020-2021. Because of threats such as stagnant yield, degradation of land and water, scarcity of irrigation water, climate change and associated problems, vulnerability in farming, and low harvested yield by farmers the potential, India faces a significant challenge in achieving much-needed agricultural sustainability to feed the populous nation. The most viable option for increasing agricultural productivity and ensuring sustainability from limited natural resources while avoiding negative consequences is to maximize resource efficiency and input use efficiency. To boost agricultural returns and assure crop production sustainability, now is the time to use current tools by combining all available technology into the agricultural platform. Precision agriculture (P.A.) combines all technology with agriculture to increase productivity while reducing input costs.

Precision agriculture (P.A.) is the science of improving crop yields and assisting management decisions using high-technology sensor and analysis tools. P.A. is a new concept adopted throughout the world to increase production, reduce labour time, and ensure the effective management of fertilizers and irrigation processes. It uses a large amount of data and information to improve the use of agricultural resources, yields, and the quality of crops (Mulla, 2013). The term "precision farming" describes the integration of GIS and GPS tools to provide extensive detailed information on crop growth, crop health, crop yield, water absorption, nutrient levels, topography, and soil variability (Adrian et al. 2005).

Precision agriculture is the application of modern information technologies to provide, process and analyze multisource data of high spatial and temporal resolution for decision making and operations in the management of crop production (National Research Council, 1997).

2. Need of Precision Agriculture

Agriculture in developing nations is currently confronted with numerous issues, and experts are proposing specific management options based on existing and established technologies. However, in an ever-changing environment, it will be challenging to meet future challenges, which may need the use of revolutionary technology-based approaches. Generally, an entire field is managed by the adoption of recommended package of practices developed on the basis of some average condition, which may or may not exist in the entire farmland. Therefore, precise crop management is needed, which can recognize site-specific variables within agricultural lands and adjust management strategies accordingly with better decision-making capability (Bhattacharyay et al. 2020). Different technologies can be used to track the variances of yield scientifically in order to improve management practises in terms of response to various yield-causing elements. Precision agriculture offers the opportunity for automation in the gathering and analysis of data for accuracy in order to make the best decision possible.

3. Components

Generally, three major components of precision agriculture are technology, information and management (Ahmad and Mahdi, 2018). Precision farming is information-intensive, and treatment maps require a large amount of data, and numerous strategies are under development or have been established in the recent decade. Earlier, precision agriculture encompassed three "R's": the right time, amount, and place (Robert et al. 1994).

3.1 Technology: Farmers must remain updated with technological advancements that can help them increase productivity and profitability. Technologies like Geographic Information Systems (GIS), sensors, remote sensing etc., can help to identify and quantify stress and nutrient deficiency of the crop. They can help with the adoption of integrated management systems for soil health, nutrients, pests, water, energy, and various crop genetic resources.

3.2 Information: Detailed information about the crop characteristics, soil properties, pests and disease incidence, climatic conditions, stress (biotic and abiotic) etc., can be used to create various kinds of maps which can help the farmers to use the available information while making decisions.

3.3 Management: Efficient management will create a complete system by combining the information gathered and the technology available. Crop production will be unfeasible without good management precision. Farmers must be able to evaluate available data, use technology effectively, and make solid production and decision-making decisions.

4. Tools of Precision Agriculture

Global Positioning System (GPS): One of the fundamental technologies that enable precision agriculture is the global positioning system (GPS). GPS receivers with enough accuracy for yield mapping, grid sampling, variable rate application, and other precision operations are available at a reasonable price. Farmers can use GPS to pinpoint field data's precise location, including soil type, pest occurrence, weed invasion, etc. Differential GPS, or DGPS, is the most prevalent method of correcting GPS inaccuracies. The differential global positioning system (DGPS) is an integration of space-based and ground-based segments that together comprise a radio-navigation facility (Shearer et al. 1999).

Geographical Information System (GIS): A GIS is a set of computer tools that allows one to work with data tied to a particular location or spatially mapped area on the earth. A GIS database is designed to work with map data (Price, 2006). GIS allows multiple detailed data to be drawn graphically, which can be used for decision-making. A farming GIS database can provide information on field topography, soil types, surface drainage, subsurface drainage, soil testing, irrigation, chemical application rates and crop yield. Once analyzed, this information is used to understand the relationships between the various elements affecting a crop on a specific site (Bharteey et al., 2019).

Sensor Technologies: Sensor technology is a key component of precision agriculture, and its usage to provide information on soil qualities and plant fertility/water status has been widely reported. Various technologies such as electromagnetic, conductivity, photo electricity and ultrasound are used to measure humidity, vegetation, temperature, texture, structure, physical character, humidity, nutrient level, vapour, air etc. Remote sensing data are used to distinguish crop species, locate stress conditions, identify pests and weeds, and monitor drought, soil and plant conditions. (Hakkim et al. 2016).

Remote Sensing: Remote sensing is the science and art of acquiring information about the earth's surface without actually coming in contact with it. This is done by recording energy, which is either reflected or emitted from the earth's surface. The recorded information is then processed and analyzed, which is used to develop a prescription map that can be used in a variable rate application (Grisso et al., 2011). It enables the identification of the landscape without the sensor coming into direct contact with the soil. It senses crop vegetation and detects crop stressors and insect infestations via aerial or satellite imagery.

Variable Rate Technology (VRT): It's a technique for applying changing rates of inputs in specific zones over a field. VRT's objectives are maximizing profit to the fullest extent possible, improving input application efficiencies, and ensuring long-term sustainability and environmental safety. These are automatic and can be applied to numerous farming operations. It sets the rate of delivery of farm inputs depending on the soil type noted in a soil map. Information extrapolated from the GIS can control processes, such as seeding, fertilizer and pesticide application, herbicide selection and application at a variable rate in the right place at the right time. (Hakkim et al. 2016).

5. Advantages of Precision Agriculture

Modern PA can help farmers increase yields and resources while decreasing environmental impacts like over-fertilization and pesticide use. It is useful for the valuation of crop stresses, quality of soils, vegetative cover, and yield estimation (Wójtowicz et al., 2016).

P.A. technologies allow farmers to alter the distribution and timing of fertilizers and other agrochemicals in their fields based on spatial and temporal variability. To acquire an accurate risk estimate, farmers can conduct economic analyses based on crop output variability.

Nitrate leaching has been a major problem in potato cropping systems, especially in coarse-textured soils. A study conducted in two adjacent fields, one treated with URT for nitrogen fertilizer and the other with VRT, has demonstrated the effect of VRT in reducing groundwater contamination (Whitley et al., 2000)

With the availability of topographic data for fields implemented with P.A. technologies, the interaction between tillage and soil/water erosion can be examined. Thus, a reduction in erosion can be achieved (Schumacher et al., 2000).

6. Constraints of Precision Agriculture

The mapping of many different soils, crop and environmental factors within a field produce large quantities of data for the crop manager to deal with. This data overload for the manager has to be overcome by the development of data integration tools, expert systems and decision support systems (Sigrimis et al., 1999).

Although data required on soil, crop and environmental factors can be obtained, most methods are labour-intensive and costly (such as soil sampling followed by laboratory analysis) (Stafford, 2000).

P.A. requires the implementation of new-age technologies. For small farmers, setting up IoT and sensor networks will become a challenge. Training farmers on different P.A. tools are of significant importance, and the success of P.A. will rely on the training (Bhattacharyay et al., 2020).

In many villages, strong, reliable internet connectivity is not available. Unless there is a significant improvement in network performances and bandwidth speeds, P.A. will remain problematic. Cloud-based computing also needs to become stronger (Bhattacharyay et al., 2020).

7. Future Scope of Precision Agriculture

The recent development of precision application technology is now allowing for smaller treatment units by making applications according to site-specific demands. The future automated systems will have sensors and computer technologies that first categorize every plant in the field as either weed or crop and then identify the species of weed (Young et al., 2014). Artificial Intelligence (A.I.) has lately been used to realize prediction, control, and/or recognition tasks in various sensing environments. Its integration with embedded systems, on the other hand, is still limited. Shradin et al., in 2019, conducted research to detect seed germination using Artificial Intelligence on low power embedded system in which they assessed the performance of the proposed embedded sensing system with the A.I. on board against a desktop computer, and the seed recognition was accurate to 97 per cent. Precision farming is a fast-growing industry. According to a study by Roland Berger Strategy Consultants GmbH, its compound annual growth rate (CAGR) is about 12%. The key to this development process is connectivity. The more significant challenge of the P.A. is handling, storing and processing the data and connecting the different devices (Gyarmati and Mizik 2020).

8. Conclusion

Precision farming offers a new system-based solution to today's agricultural issues, such as the need to balance productivity and environmental concerns. It aims to increase economic returns while lowering agricultural energy input and environmental impact. In many developing nations such as India, precision farming is still a work in progress and has a long way to go. Its success primarily depends on how well and quickly the information required to guide the new technology can be discovered. To encourage the swift adoption of P.A. technologies, deliberate support from the public and private sectors is crucial to make it cost-effective and beneficial for the farmers. A big hurdle for the developers remains the extensive land fragmentation in India as the majority of the farmers are small and marginal and hence have less than 2 hectares of land, and for them adopting expensive Precision Agriculture technologies would not be cost-effective. The environment and farmers will benefit from the efficient use of resources, but there will also be various challenges regarding data security, training, e-waste, technology malfunction, loss of jobs, etc.

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